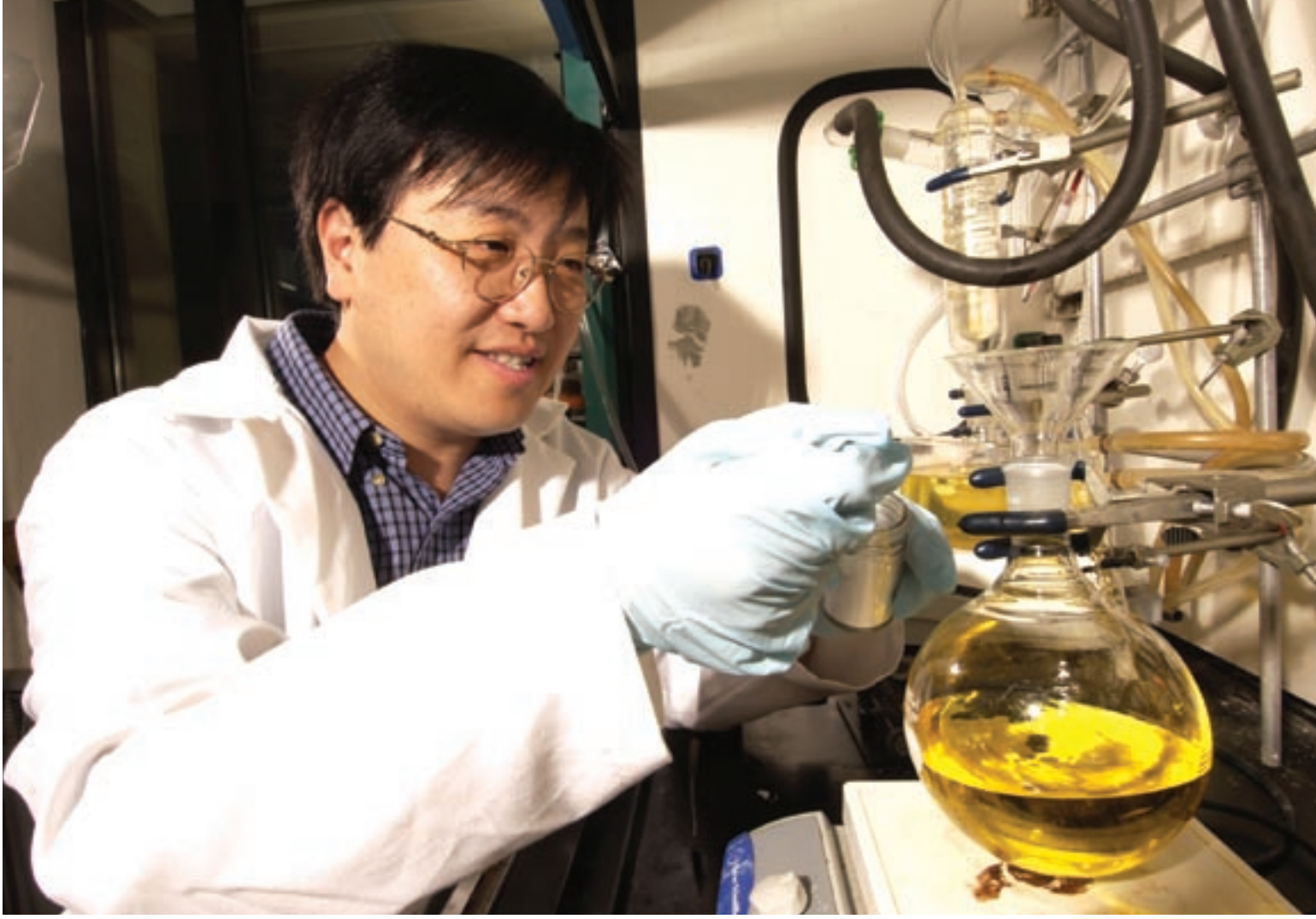
From Farm Field to Fuel Tank

Biodiesel gains attention as an alternative fuel source

by Steve Karsjen

A person need look no further than articles in their local newspaper to know that something needs to be done to help curb our nation's dependence on domestic and foreign oil. Elevated prices have made any type of major diesel-fuel users, whether they be farmers, fleet managers or municipalities, painfully aware of the necessity of finding alternative fuel sources. And where better to look for these sources than Iowa's farm fields. As a national leader in soybean production, with crop projections of over 350 million bushels in 2003, Iowa's soybean farmers stand to make an enormous contribution to our nation's energy independence.

Photo courtesy of USDA Natural Resources Conservation Service



Victor Lin adds some heterogeneous catalyst to soybean oil to create biodiesel.

Soydiesel, or biodiesel, is one of the products gaining favor as an alternative fuel because it's clean burning and biodegradable and can be made from a renewable resource, in this case, soybeans. It's also being eyed as a more environmentally friendly industrial solvent that could be used for the removal of graffiti or for cleaning up oil spills. But there are several keys to making soydiesel more attractive as a fuel – some related to the fact that industry is not geared up to produce biodiesel on a large scale. Other more significant issues relate to the costs of producing it and disposing of the wastes created by the production process.

The effort to discover more efficient catalysts got its start with the help of a Science with Practice grant from the Iowa State University Center for Catalysis and the Ames Laboratory Biorenewable Resources Consortium. The successful results of that research led to the awarding of a $1.2 million grant from the U.S. Department of Energy and U.S. Department of Agriculture, which will be used to study new technologies for production of methyl ester, or biodiesel, from soybeans.

"Our new technology has the potential to reduce energy consumption, enhance economic competitiveness and lower the environmental imprint of methyl ester production," says George Kraus, director of the BRC and the CCAT, and an ISU professor of chemistry.

Catalysts are key to converting triglycerides like soybean oil to biodiesel. To create biodiesel from soy oil, scientists perform a chemical reaction whereby they replace the glycerol in the oil with methanol. This process requires the use of a catalyst. Catalysts are used to speed up the rates of chemical reactions without getting used up in those reactions themselves. The current process to convert soy oil into soydiesel relies on the use of homogeneous catalysts. The process, called transesterification, replaces one ester in the soy oil with another to create biodiesel.

But there are problems with using homogeneous catalysts to manufacture soydiesel. In the example just mentioned, sodium methylate is the preferred homogenous catalyst. It mixes with methanol and soybean oil to create biodiesel. Because it is a strong caustic and corrosive base, the remaining sodium methylate in the biodiesel product mixture cannot be reused and must be neutralized with an acid, which adds unwanted expense to the biodiesel production process.

Also in the mix, is an expensive waste-storage problem because homogeneous catalysts are not easily recyclable. In

Victor Lin and graduate students Hung-Ting Chen and Jennifer Nieweg line up behind samples (left to right) of poultry fat, soybean oil and biodiesel.

addition, the time it takes to do all of this is another factor. When combined, these issues make biodiesel production less financially attractive to producers, like West Central Cooperative of Ralston, Iowa. West Central is a large, farmer-owned cooperative in west central Iowa that annually processes approximately 72 million pounds of soy oil into biodiesel. West Central sells this product to distributors nationwide.

"The success of biodiesel all comes down to costs," says Myron Danzer, sales and production manager for West Central. And like any business, West Central wants to keep costs down and profits high. Doing so will require reducing the costs to produce biodiesel and eliminating the waste problem that comes with using homogeneous catalysts in the transesterification process.

The solution to both problems could lie in the development of heterogeneous catalysts. Because heterogeneous catalysts can be easily separated from the product by filtration, using them eliminates the expense of having to add acid to the biodiesel production mix. Also, in contrast to the nonrecyclable homogeneous catalysts, the heterogeneous catalysts can be reused many times, which further lowers the cost of the biodiesel production.

To find someone doing research in the area of heterogeneous catalysts, West Central had to travel only about 60 miles up the road to the Ames Laboratory and Iowa State University. Catalysis is currently a research thrust of the Ames Lab's Biorenewable Resources Consortium and Victor Lin, an Ames Lab chemist and an ISU assistant professor of chemistry. Lin's research is in the production of heterogeneous catalysts. Through the DOE/USDA grant, Lin and West Central are collaborating to scale up production of test heterogeneous catalysts, analyze tests and design equipment to mass produce new catalysts.

The effort to design a more efficient biodiesel conversion process revolves around Lin's work in the area of "mesoporous silica nanocatalysts." These honeycombed particles speed up the conversion process and can be more easily separated and recycled after they've done their job.

"If we can replace the homogeneous catalyst with one that's heterogeneous, it would allow us to isolate the catalyst and also recycle it so we don't have to waste time and effort trying to neutralize the base catalyst with the acid," says Lin.

Free Fatty Acids

Creating biodiesel from soybeans is just one chapter of the story for Ames Laboratory and West Central. The cooperative would like to expand the variety of products it uses as feedstock to produce biodiesel. One of the items at the top of the list of potential "other" materials is corn. Iowa farmers harvested around 1.87 billion bushels of corn in 2003, so the potential exists for a major market for this product. Other feedstocks also on the list are poultry fat and waste grease. "We want the capability of using what they call multiple feedstock," says Danzer.

Unfortunately, these feedstocks are more expensive to turn into biodiesel than soy oil because they contain a small amount of free fatty acid, or FFA. Some oils oxidize, or become acids if they sit too long. Then they hydrolyze and react with the base, forming a salt that kills the base catalyst before the base can react with the methanol used to create biodiesel.

"So what we're trying to do is create a catalyst that instead of being a base is actually an acid, which will eliminate the free fatty acids before the oils go through the conversion process to produce biodiesel," says Lin. "If companies like West Central can solve this free fatty acid problem, they would be able to really open up their markets," he adds. "For example, there's a 10 cent per pound cost difference between using poultry fat than using soybean oil to create biodiesel."

Two-fold process

At the same time Lin is working on the free fatty acid problem, one of his colleagues, John Verkade, an Ames Laboratory associate scientist and an ISU professor of chemistry, is working to develop a "superbase" catalyst he patented through ISU that would more efficiently conduct the transesterification

process, that is converting the triglycerides to biodiesel. "So my participation is to help John design a system to actually turn the homogeneous superbase catalysts into heterogeneous systems so these catalysts can be recycled," says Lin. But going beyond that, Lin says he has developed a new heterogeneous alphacatalyst, containing both an acid and a superbase, which would eliminate the free fatty acids and also do the transesterification.

"What you'd have is a heterogeneous double catalyst," says Verkade, "one that would convert both the FFA and triglyceride to biodiesel."

Lin adds, "Having one catalyst doing two jobs would be like killing two birds with one stone." He notes that this next generation super-efficient catalyst would be useful to industry in many ways. "Efficiency is what they're after, so we would be lowering the costs associated with producing biodiesel as well as making the catalysts recyclable."

As one might imagine, all of this is music to the ears of West Central Cooperative. "Our interaction with Victor Lin has been great," says Danzer. "They get input from us on the practical commercial applications, and we get the detailed science."

Lin says the cooperative is looking beyond just being able to produce biodiesel fuel. "It is also considering selling the overall production design to potential clients," he says. "Let's say, for example, that California wants to build a biodiesel plant. They could come to West Central and purchase an entire design package. That would be good for them and good for us because they would have to buy the catalyst from us."

West Central has actually taken steps to get this process started. It has formed a partnership with another Iowa company to build what Danzer calls "turnkey" plants for other companies.

Lin believes the Ames Laboratory scientists are on the right track to make biodiesel a competitive alternative fuel. "I think we're at a crucial juncture that will require both know-how and government funding," he says.

"Tooling up" the biodiesel production process will require a major change in infrastructure because that infrastructure is currently based on fossil fuels, says Lin. And changing infrastructure always costs money, which he says is where the government comes in. "If some changes are made, we could see the market for biodiesel really open up," Lin concludes.

For more information:
Victor Lin, (515) 294-3135
vslin@iastate.edu

Research funded by:
U.S. Department of Agriculture

A worker at the West Central Cooperative processing plant kneels beside a pair of decanters used to separate the lighter methyl esters from the heavier glycerine.

Photo courtesy of West Central Cooperative